

## CLAIMS

### WHAT IS CLAIMED IS:

1. A composition comprising a plurality of structurally ordered nanostructures in a matrix.
2. The composition of claim 1, wherein the structurally ordered nanostructures comprise substantially non-randomly oriented nanostructures.
3. The composition of claim 2, wherein the non-randomly oriented nanostructures comprise nanostructures substantially aligned with respect to one another.
4. The composition of claim 2, wherein the non-randomly oriented nanostructures comprise nanostructures substantially aligned with respect to a selected axis.
5. The composition of claim 4, wherein the composition is positioned proximal to a substrate, and the selected axis is substantially perpendicular to a surface of the substrate.
6. The composition of claim 1, wherein the plurality of structurally ordered nanostructures comprises a substantially regularly-ordered array of nanostructures.
7. The composition of claim 1, wherein the plurality of structurally ordered nanostructures comprises an irregularly-ordered arrangement of nanostructures.
8. The composition of claims 1, wherein the nanostructures comprise spherical, ovoid, elongated or branched structures.
9. The composition of claim 8, wherein the nanostructures comprise nanocrystals, nanodots, nanospheres, nanorods, nanowires, nanotetrapods, dendrimer branching structures, or combinations thereof.
10. The composition of claim 8, wherein the nanostructures comprise inorganic nanostructures.
11. The composition of claim 1, wherein the matrix comprises one or more components that interact to form a plurality of receiving structures that provide ordering and/or an orientation to the nanostructures.

12. The composition of claim 11, wherein the components of the matrix self-assemble to form the matrix.
13. The composition of claim 11, wherein one or more components of the matrix are chemically crosslinked or capable of chemically cross-linking to one another.
14. The composition of claim 11, wherein one or more components of the matrix are chemically cross-linked or capable of chemically cross-linking to one or more of the nanostructures.
15. The composition of claim 14, wherein a component of the matrix comprises multiple nanostructure-binding components.
16. The composition of claim 1, wherein the composition comprises two or more matrix layers, each member layer comprising a plurality of structurally ordered nanostructures.
17. The composition of claim 16, wherein the member nanostructures in a first matrix layer are substantially aligned with respect to the member nanostructures in an adjacent matrix layer.
18. The composition of claim 16, wherein the member nanostructures in a first matrix layer are not substantially aligned with respect to the member nanostructures in an adjacent matrix layer.
19. A composition comprising a plurality of structurally ordered nanostructures, wherein members nanostructures comprise one or more alignment ligands associated with the nanostructures, and wherein a first alignment ligand on a first member nanostructure interacts with a second alignment ligand on an adjacent member nanostructure, thereby structurally ordering the plurality of nanostructures.
20. The composition of claim 19, wherein the structurally ordered nanostructures comprise substantially non-randomly oriented nanostructures.
21. The composition of claim 20, wherein the structurally ordered nanostructures comprise substantially aligned nanostructures.
22. The composition of claim 19, wherein the first and second alignment ligands comprise the same molecule.

23. The composition of claim 19, wherein the first and second alignment ligands comprise different molecules.
24. The composition of claim 19, wherein the first and second alignment ligands comprise self-organizing molecules.
25. The composition of claim 19, wherein the first and second alignment ligands comprise complementary binding pairs.
26. The composition of claim 25, wherein the complementary binding pairs comprise two or more molecules having a selected molecular recognition functionality.
27. The composition of claim 26, wherein the first and second alignment ligands comprise an amine-containing moiety or an alcohol-containing moiety, or both.
28. The composition of claim 26, wherein the first and second alignment ligands comprise one or more biomolecule pairs.
29. The composition of claim 28, wherein the biomolecule pair comprises an antibody and an antigen that binds to the antibody; biotin and avidin; a lectin and a carbohydrate ligand; complementary nucleic acids; a protein and a ligand; a receptor and a ligand; an aptamer and an aptamer ligand; or a combination thereof.
30. The composition of claim 19, wherein the first alignment ligand and/or the second alignment ligand comprise two or more selected molecular recognition functionalities per alignment ligand.
31. The composition of claim 19, wherein the nanostructures comprise spherical, ovoid, elongated or branched structures.
32. The composition of claim 31, wherein the nanostructures comprise nanocrystals, nanospheres, nanorods, nanowires, nanotrapods, dendrimer branching structures, or combinations thereof.
33. The composition of claim 19, wherein the interaction between the first and second alignment ligands comprises an ionic interaction, a covalent interaction, a hydrogen bond interaction, an electrostatic interaction, a coulombic interaction, a van der Waals force interaction, or a combination thereof.

34. The composition of claim 19, wherein the first and second alignment ligands comprise one or more functionalized head group capable of binding to a nanostructure surface or to a ligand associated with the nanostructure surface.

35. The composition of claim 34, wherein the functionalized head group comprises one or more phosphonic acid, carboxylic acid, amine, phosphine, phosphine oxide, carbamate, urea, pyridine, isocyanate, amide, nitro, pyrimidine, imidazole, salen, dithiolene, catechol, N,O-chelate ligand, P,N-chelate ligand, or thiol moieties.

36. The composition of claim 34, wherein the chelate N,O ligand comprises ethanol amine or aniline phosphinate.

37. A plurality of clusters of structurally ordered nanostructures on a substrate.

38. The plurality of nanostructure clusters of claim 37, wherein the structurally ordered nanostructures comprise selectively-oriented nanostructures.

39. The plurality of nanostructure clusters of claim 37, wherein an orientation of the selectively-oriented nanostructures is substantially aligned with a selected axis.

40. The plurality of nanostructure clusters of claim 39, wherein the selected axis is substantially perpendicular with respect to a surface of the substrate.

41. The plurality of nanostructure clusters of claim 39, wherein the selected axis is substantially parallel with a surface of the substrate.

42. The plurality of nanostructure clusters of claim 37, wherein the nanostructures comprise nanorods or nanowires.

43. A method of structurally ordering nanostructures in a matrix, the method comprising:

providing a plurality of nanostructures and a matrix composition, wherein the matrix composition comprises one or more matrix components that interact to form a plurality of receiving structures capable of accommodating the nanostructures; and,

heating and cooling the matrix composition in the presence of the plurality of nanostructures, thereby ordering the plurality of nanostructures in the matrix.

44. The method of claim 43, wherein the ordering provides a plurality of non-randomly oriented and/or or non-randomly dispersed nanostructures in the matrix.

45. The method of claim 43, wherein providing the matrix composition comprises providing the one or more matrix components in a non-ordered form, and wherein heating and cooling the matrix composition in the presence of the plurality of nanostructures comprises thermodynamically ordering the matrix around the plurality of nanostructures.

46. The method of claim 43, wherein providing the matrix composition comprises providing a pre-formed matrix having the plurality of receiving structures capable of accommodating the nanostructures; and wherein heating and cooling the matrix composition in the presence of the plurality of nanostructures comprises inserting the nanostructures into one or more of the plurality of receiving structures.

47. The method of claim 43, further comprising cross-linking the one or more matrix components.

48. A plurality of structurally ordered nanostructures in a matrix as prepared by the method of claim 43.

49. A method for preparing a plurality of structurally ordered nanostructures, comprising:

providing a plurality of nanostructures comprising a first set of nanostructures associated with a first alignment ligand and a second set of nanostructures associated with a second alignment ligand; and,

interacting the first alignment ligand on a first nanostructure with the second alignment ligand on a second adjacent nanostructure, thereby structurally ordering the plurality of nanostructures.

50. The method of claim 49, wherein the plurality of structurally ordered nanostructures comprises a plurality of selectively-oriented nanostructures.

51. The method of claim 49, wherein the nanostructures comprise spherical, ovoid, elongated or branched structures.

52. The method of claim 52, wherein the nanostructures comprise nanocrystals, nanospheres, nanorods, nanowires, nanotrapods, dendrimer branching structures, or combinations thereof.

53. The method of claim 49, wherein providing the plurality of nanostructures comprises:

- preparing a plurality of nanostructures;
  - vapor phase depositing the first alignment ligand on a surface of a first portion of the plurality of nanostructures; and,
  - vapor phase depositing the second alignment ligand on a surface of a second portion of the plurality of nanostructures to produce nanostructure-alignment ligand conjugates.
54. The method of claim 53, wherein the plurality of nanostructures are prepared by vapor deposition onto a substrate.
55. The method of claim 53, wherein the plurality of nanostructures are prepared by solution phase deposition.
56. The method of claim 54, further comprising:  
removing the nanostructure-alignment ligand conjugates from the substrate prior to interacting the first and second alignment ligands.
57. The method of claim 53, wherein the first and second portions of the plurality of nanostructures comprise separate populations of nanostructures.
58. The method of claim 53, wherein the first and second portions of the plurality of nanostructures comprise separate regions of individual nanostructures.
59. The method of claim 49, wherein the first and second alignment ligands comprise one or more complementary binding pairs.
60. The method of claim 59, wherein the one or more complementary binding pair comprise molecules having a selected molecular recognition functionality or self organizing molecules.
61. The method of claim 59, wherein the complementary binding pair comprises an amine-containing compound and an alcohol-containing compound.
62. The method of claim 59, wherein the complementary binding pair comprise a biomolecule pair.
63. The method of claim 49, further comprising:  
coupling the first alignment ligand to a surface of the first nanostructure and coupling the second alignment ligand to the second adjacent nanostructure, wherein the first and second alignment ligands further comprise a functionalized head group for binding the alignment molecule to the nanostructure surface.

64. The method of claim 63, wherein the functionalized head group comprises one or more phosphonic acid, carboxylic acid, amine, phosphine, phosphine oxide, carbamate, urea, pyridine, isocyanate, amide, nitro, pyrimidine, imidazole, salen, dithiolene, catechol, N,O-chelate ligand, P,N-chelate ligand, or thiol moieties.
65. The method of claim 49, wherein interacting the first and second alignment ligands comprises heating and cooling the plurality of nanostructures.
66. The method of claim 49, wherein the first and second alignment ligands further comprise a crosslinking or polymerizable element, and wherein interacting the first and second alignment ligands further comprises crosslinking or polymerizing the first and second alignment ligands.
67. The method of claim 49, further comprising:  
affixing the plurality of structurally ordered nanostructures to a substrate; and,  
removing the first and second alignment ligands.